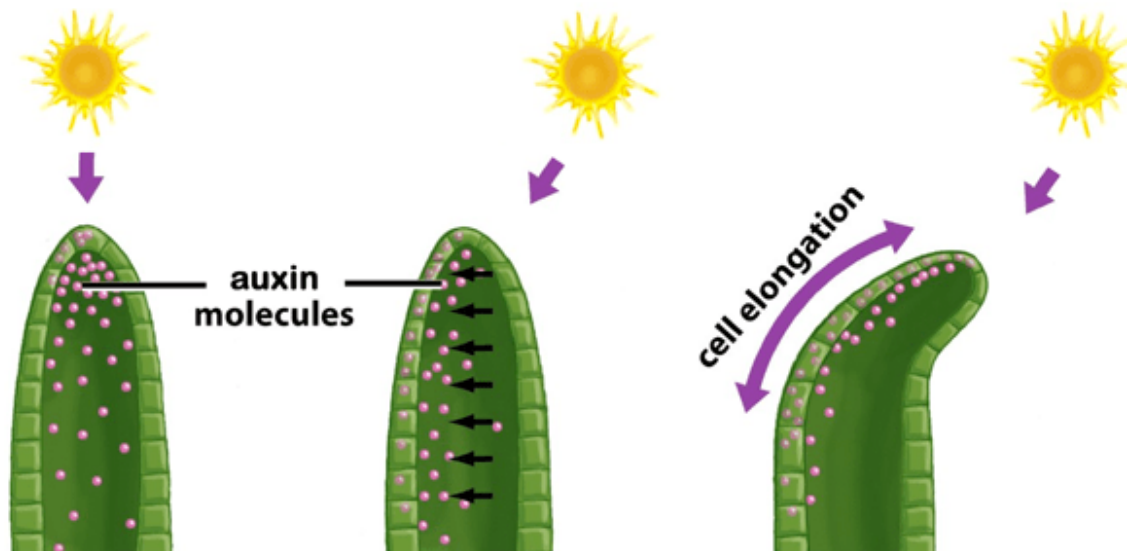




Cambridge Assessment
International Education

A2 Level Chapter 14 (Part 3)
+Chapter 15 (Part 3)

VENUS FLY TRAP + PLANT HORMONES



Chapter Outline

Electrical communication in plants (C15)

- **Venus fly trap**

Chemical communication in plants

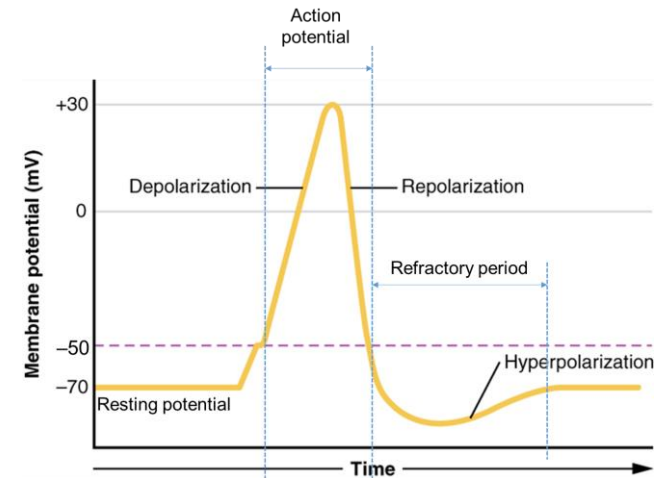
- Role of **auxin** in elongation growth (C15)
- Role of **gibberellin** in germination of wheat/barley (C15)
- Role of **gibberellin** in stem elongation (incl. role of dominant allele, *Le*) (C15)
- Role of **Abscisic Acid** During Water Stress (C14)
 - Stomata
 - Structure and Function of Guard Cells
 - Stoma Opening and Closing Mechanism
 - calcium ions = second messenger

Electrical Communication In Plants

- Only in certain plant species

Similarities:

- Have electrochemical gradients
- Plant cells have sodium-potassium pumps
- Have resting potential
- Membrane depolarises → action potentials

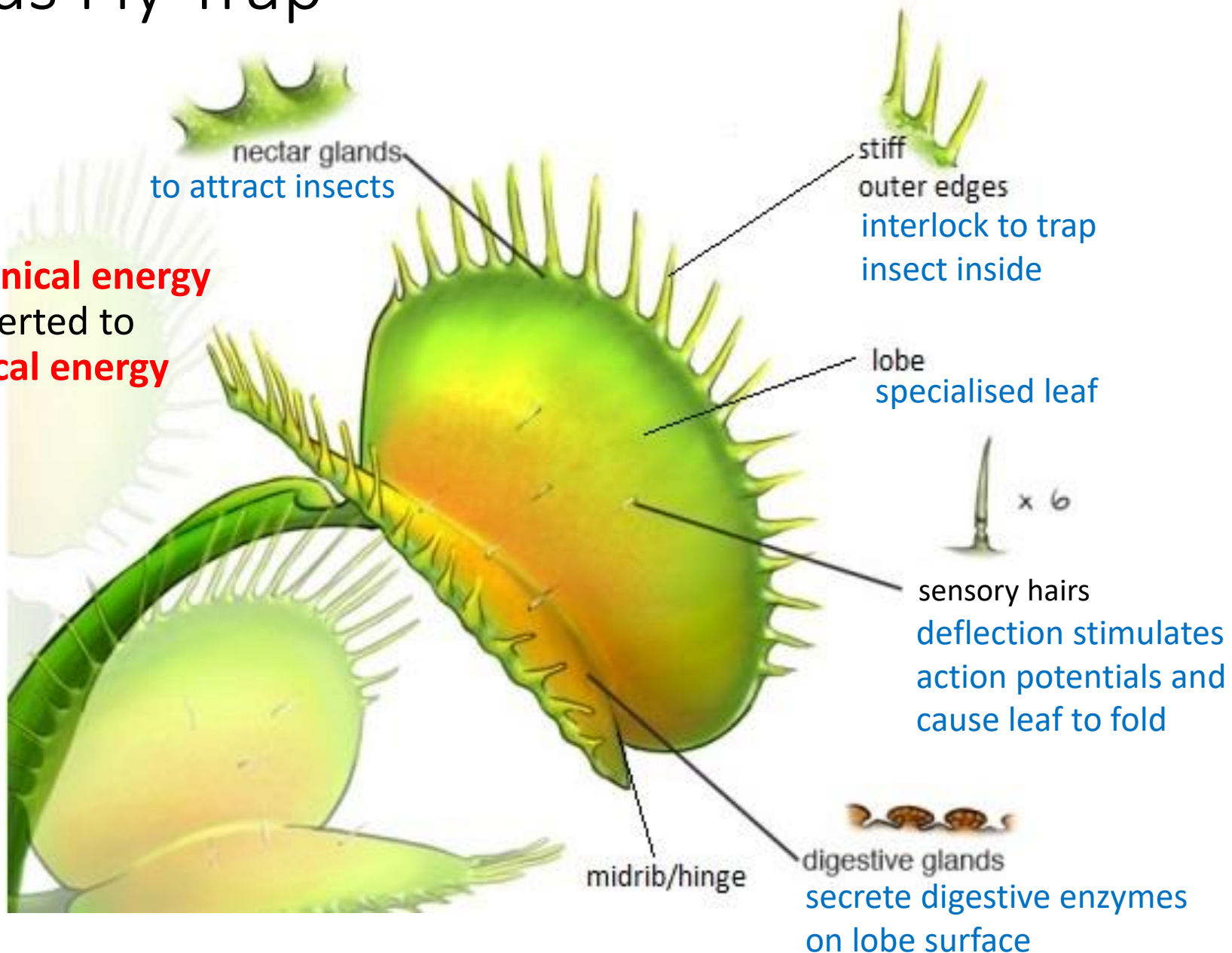


Differences:

Feature	Mammals	Plants
Depolarisation due to	Na^+ enter	Cl^- move out
Action potential travels along	Neurones	Cell membrane and cell-to-cell via plasmodesmata
Speed of transmission	Faster	Slower

Venus Fly Trap

- **Mechanical energy** is converted to **electrical energy**



BBC

Venus Fly Trap

1. **Sensory hair cell** is receptor and detects touch

- If **2 hairs** are touched / 1 hair is touched twice within 35 seconds...

- Ca^{2+} ion channels open @ cells at base of hair

- **Ca^{2+}** flow in

- Cell membrane depolarised

→ **Action potential** occurs

- **Depolarisation spreads** over leaf / **lobe**

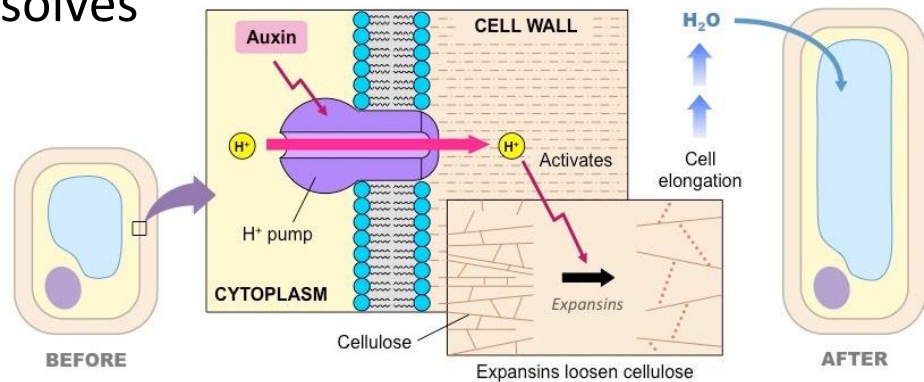
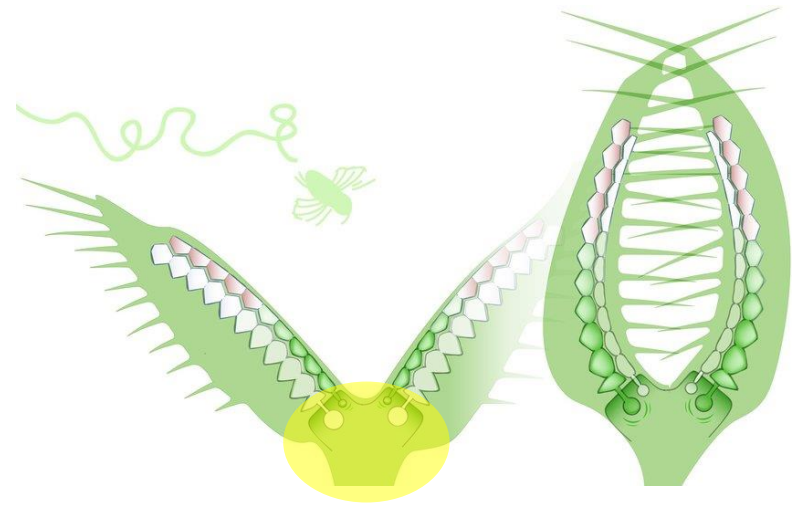
→ to midrib / **hinge cells**



Venus Fly Trap

2. **Acid growth** @ hinge cells

- **H⁺** pumped out of cells into **cell walls**
- **Cross-links** in cell wall broken
- Calcium pectate of middle lamella dissolves
- **Cell wall loosens**
- **Ca²⁺** enter hinge cells
- **Water enters** hinge cells by **osmosis**
- **Cells expand** / become turgid
- Lobes change from **convex to concave**
- **Trap shuts** quickly in 0.3s
- Elastic tension released



Venus Fly Trap



3. Further deflections of sensory hairs

- Trigger **action potentials** → seal trap
- Stimulate entry of **Ca^{2+}** into gland cells
- Ca^{2+} stimulate **exocytosis of vesicles containing digestive enzymes**
- Trap stays shut for up to 1w for digestion

4. After digestion, cells of upper surface of midrib grow slowly

- Leaf reopens and elastic tension builds in the cell walls of midrib

Venus Fly Trap

Two adaptations to conserve energy and avoid closing unnecessarily:

1. **Stimulation of single hair does not trigger closure**

→ At least two hairs must be touched OR one hair touched twice within 35 seconds

→ Prevent trap from closing when raining or when debris fall into trap

2. **Gaps between stiff hairs allow very small insects to crawl out**

→ No energy wasted on digesting a very small meal



Chemical Communication in Plants

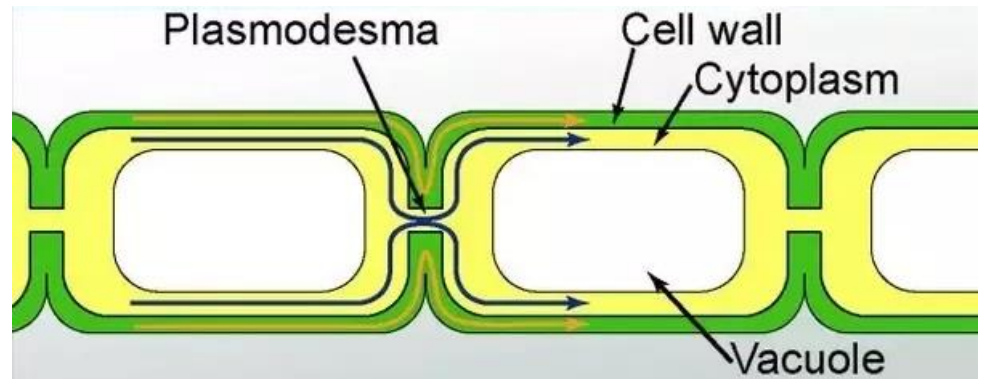
- **Plant hormones/plant growth regulators**
- **Produced in a variety of plant tissues**
- Not in endocrine glands
- Plant hormones interact with receptors inside/outside cell and initiate a signaling cascade

Movement of plant hormones:-

a) Directly from **cell to cell**

→ By active transport or diffusion

b) **Via phloem/xylem vessels**



E.g. Auxins, gibberellins, abscisic acid

Plant Hormones

1. Auxins (IAA)

- Growth by cell elongation at tips of roots and shoots
- Inhibits lateral growth / branching – i.e. apical dominance
- Via **acid growth hypothesis**

2. Gibberellins (GA)

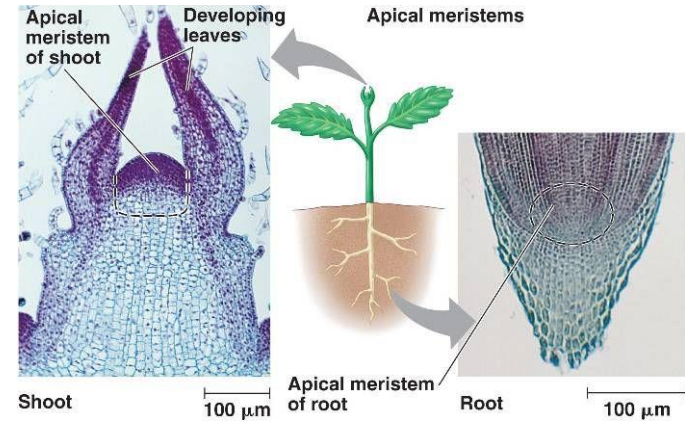
- Seed germination
- Stem elongation
- Causes **breakdown of DELLA proteins**, which are inhibitors of cell growth and seed germination

3. Absciscic acid (ABA)

- Respond to water stress
- Stimulate closure of stomata
- Uses **Ca²⁺ as second messenger**

1) Auxins (IAA)

- Group of several chemicals
- Main auxin = **IAA** (indole 3-acetic acid)
- Synthesized in **growing tips of shoots & roots**
→ Aka apical meristems where there is active mitosis



Role of auxin:

1. **Stimulate cell elongation**
2. **Inhibits lateral growth / branching** – i.e. apical dominance
→ Cause plants to grow taller towards light

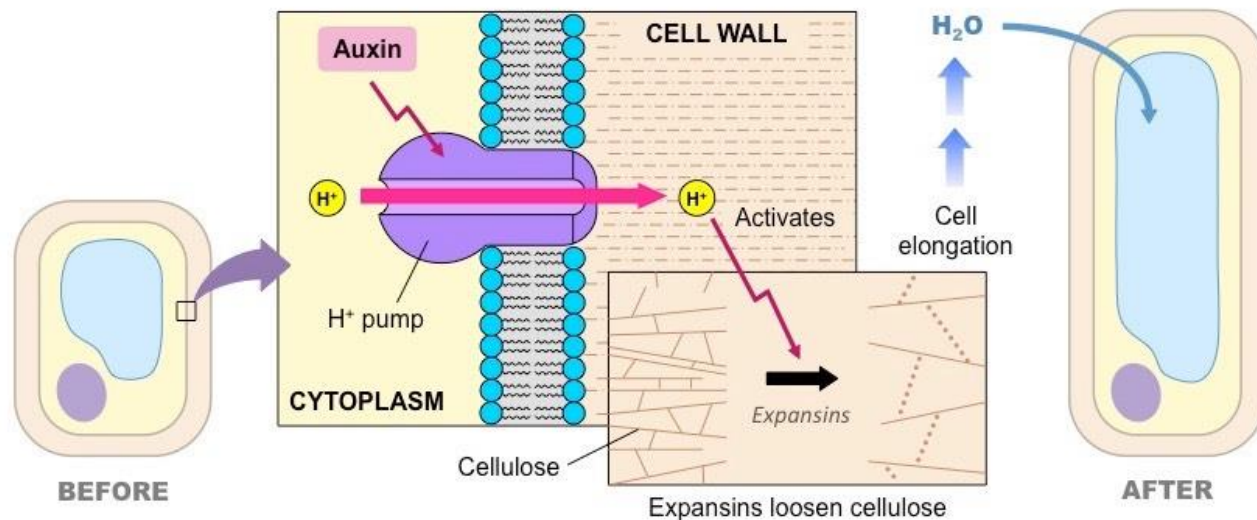
P/S: Auxin not solely responsible for apical dominance

- There is interaction between auxin and other plant growth regulators
- Gibberellin enhances IAA

Role of Auxin in Cell Elongation

The Acid Growth Hypothesis

1. Auxin binds to **receptors** in cell surface membrane
2. Stimulates **proton pumps** in cell surface membrane
 - By active transport
 - H^+ from cytoplasm into cell wall
 - **Cell wall become more acidic**



Role of Auxin in Cell Elongation

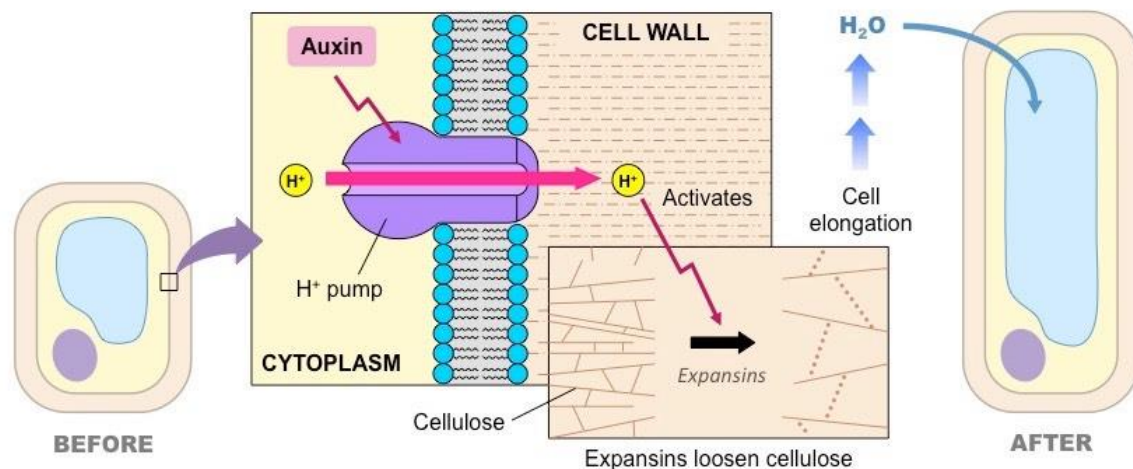
The Acid Growth Hypothesis

3. pH-dependent enzymes (**expansins**) activated to weaken cell wall

- By **breaking H bonds between cellulose microfibrils**
- Cell wall loosens → more elastic, can stretch

4. Ions enter cell and water potential of cell decreases

- **Water enter cell** by osmosis
- Increase in turgor pressure
- Cell wall expands
- Cause **elongation of cell**

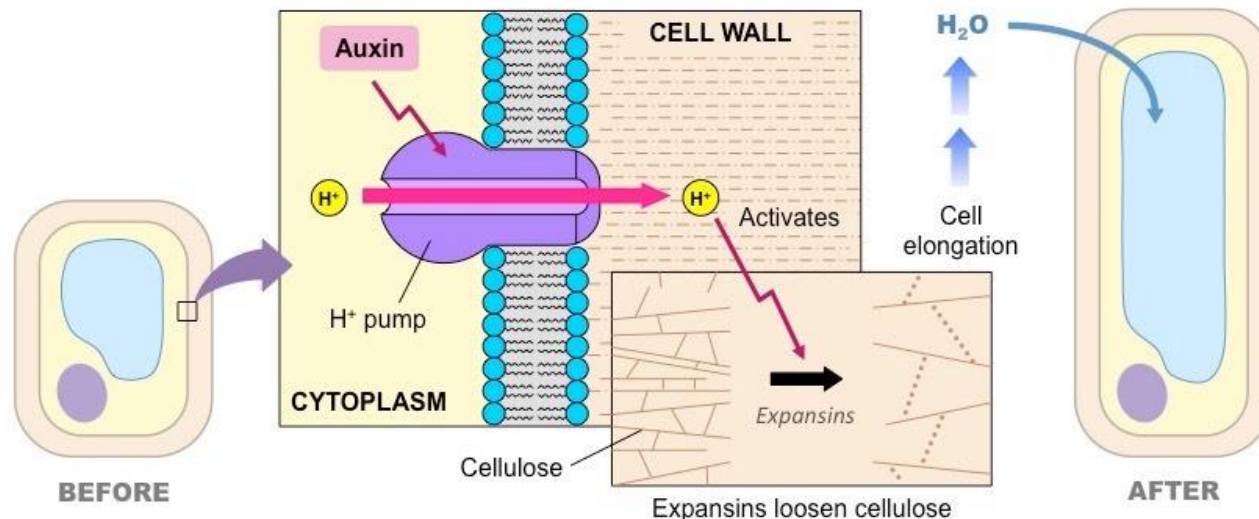


Role of Auxin in Cell Elongation

The Acid Growth Hypothesis

Hypothesis supported bcs....

1. Cell elongation can be prevented by **neutralising the acidity** of cell wall using a buffer
2. Can cause cell elongation by **acids**
3. **Protons released** from cells in response to auxin

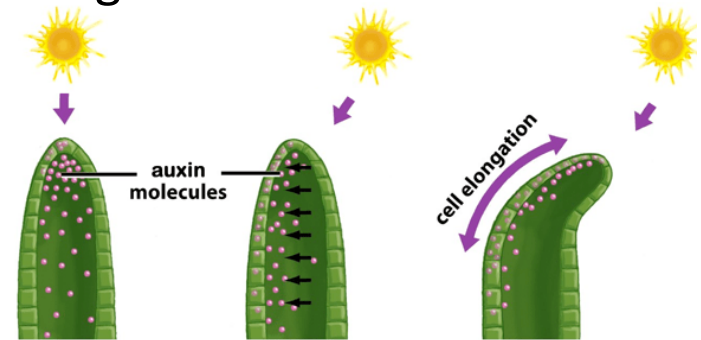


Role of Auxin in Cell Elongation

- Uneven distribution of auxin can cause stem / root to bend in respond to stimuli

→ **Higher concentration of auxin, more cell elongation**

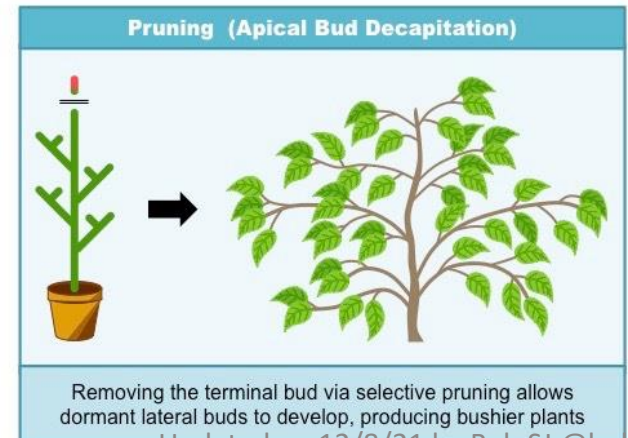
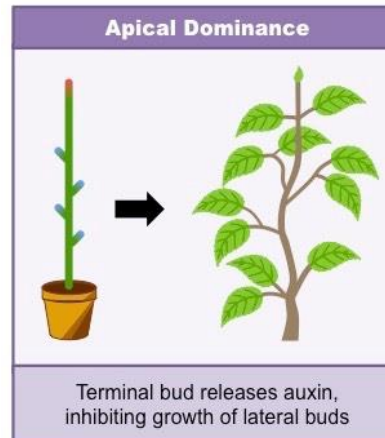
→ E.g. auxin causes shoots to bend towards sunlight



- **Auxin inhibits lateral growth** at growing tips of shoots

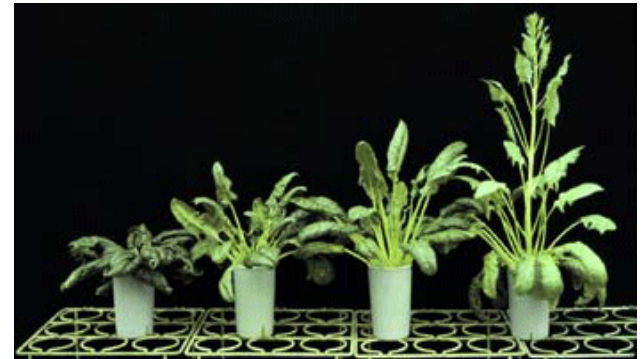
→ The act of pruning removes auxin

→ Allows branching and produces bushier plants



2) Gibberellins (GA)

- Plant growth regulator / plant hormone
- Synthesized in **young leaves, seeds & stems**
- Roles:
 1. **Seed germination**
 2. Stimulates **cell division** and **cell elongation in stem**

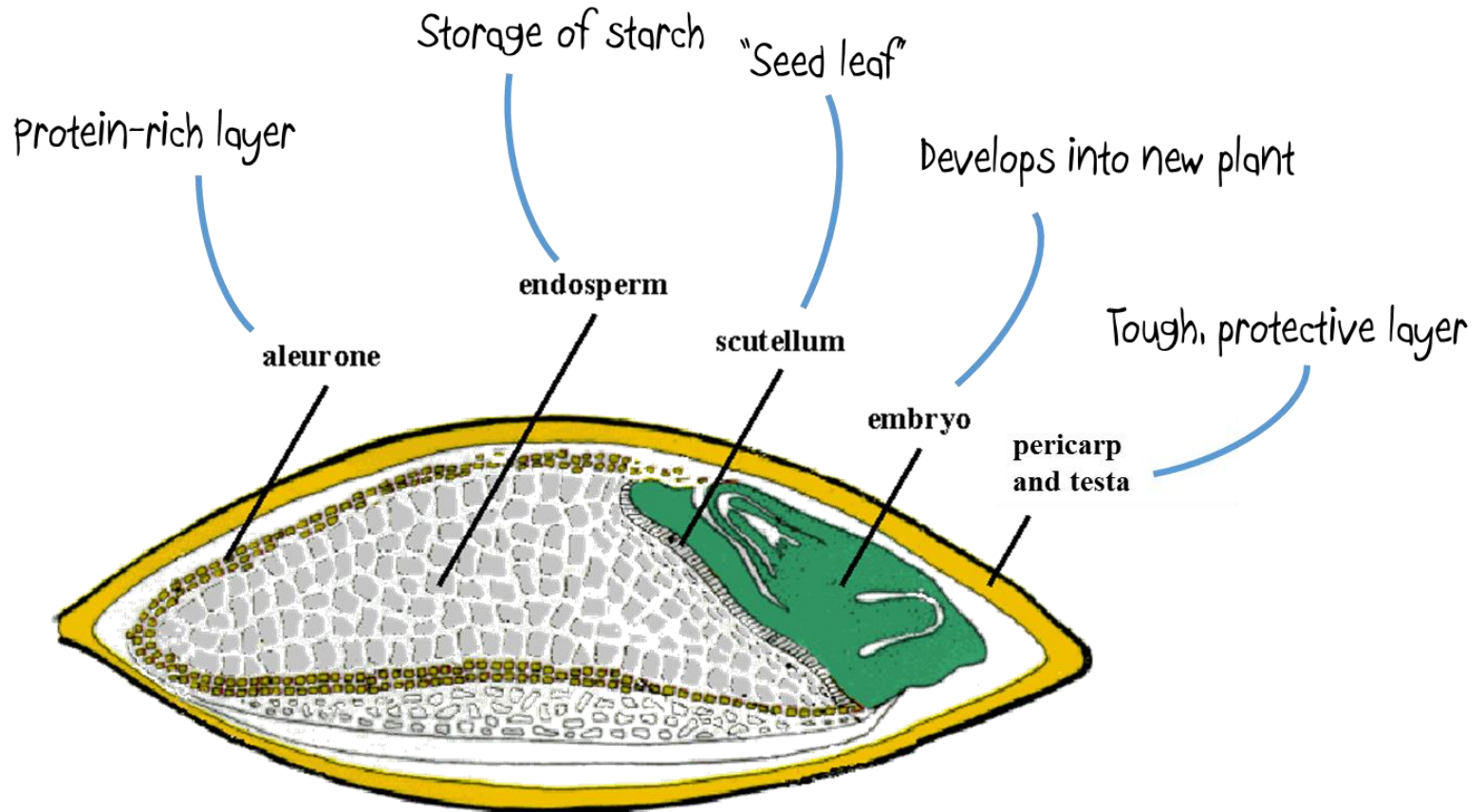


P/S: There is interaction between gibberellin and other plant growth regulators

- Gibberellin enhances IAA

Role of Gibberellin in Seed Germination

E.g. wheat and barley



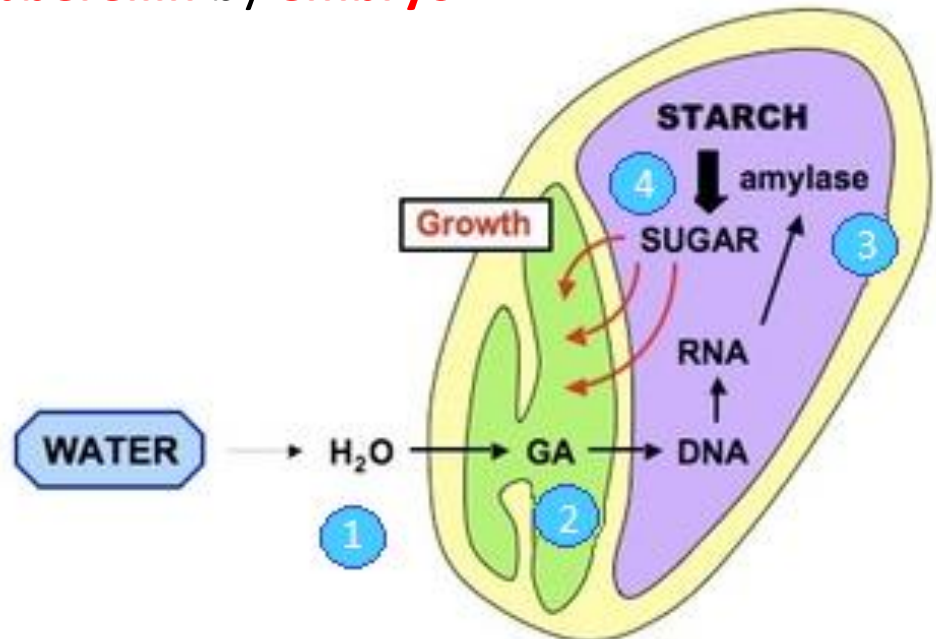
Role of Gibberellin in Seed Germination

- **Seed is dormant** / metabolically inactive

→ **DELLA proteins** act as **inhibitors** of cell growth and seed germination
→ Maintain seed dormancy

1. Seed absorbs **water** by **osmosis**

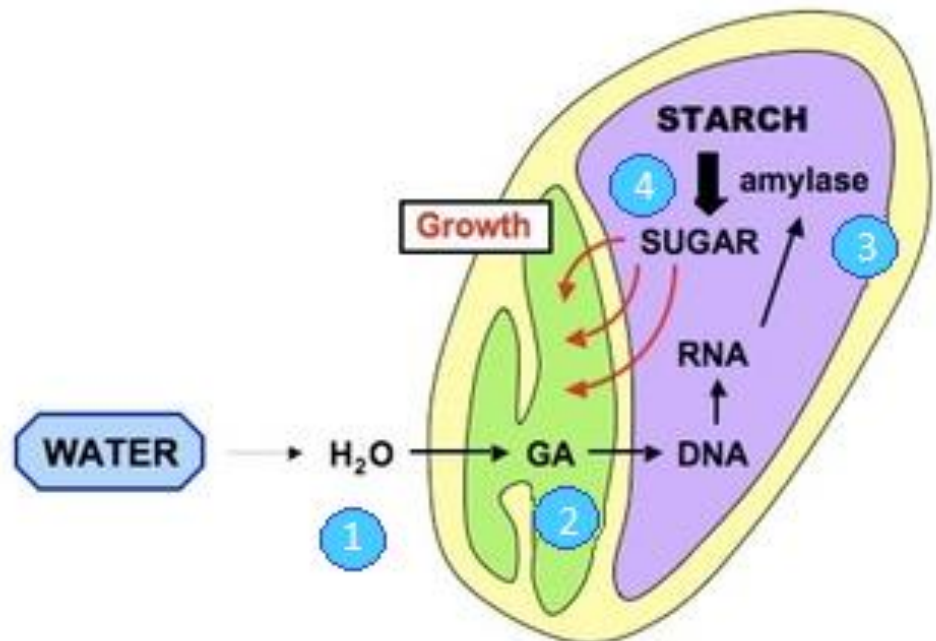
→ Water stimulates production of **gibberellin** by **embryo**



Role of Gibberellin in Seed Germination

2. Gibberellin **diffuses into cells of aleurone layer**

- Causes **breakdown of DELLA proteins**
 - Switches on **genes coding for hydrolytic enzymes** (e.g. amylase)
 - **Storage proteins** in aleurone **broken down** into amino acids
- Stimulate **synthesis of amylase**



Role of Gibberellin in Seed Germination

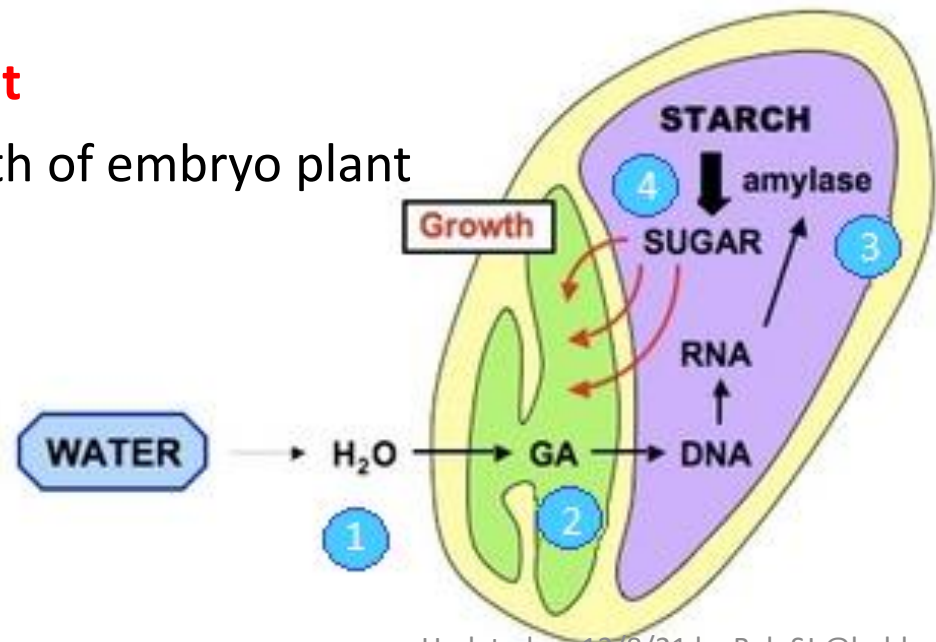
3. **Amylase** diffuses into **endosperm** (tissue surrounding embryo)

- Hydrolyses starch to maltose in endosperm
- Maltose converted to glucose



4. **Glucose diffuses into embryo plant**

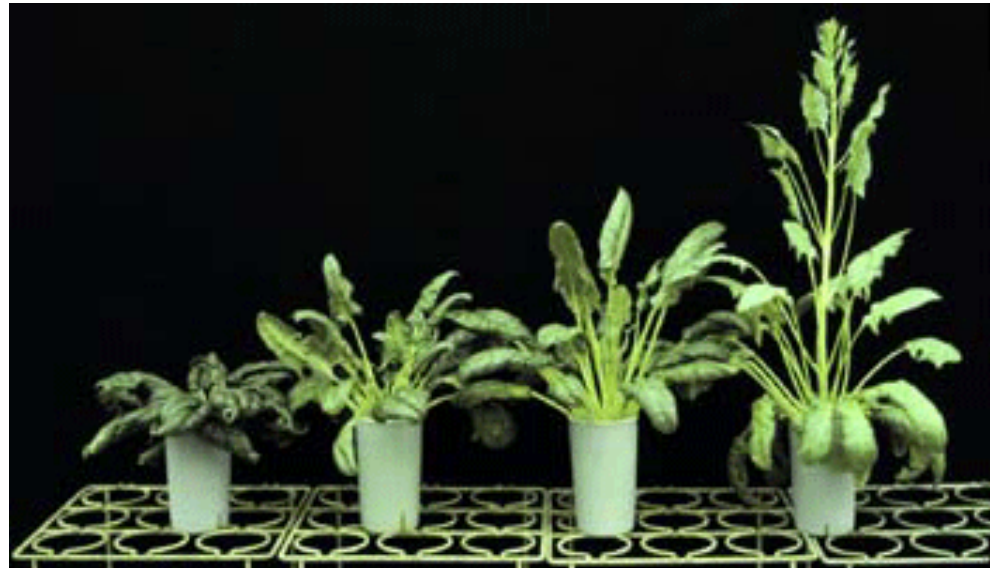
- Provides source of energy for growth of embryo plant



Role of Gibberellin in Stem Elongation

Control of Gibberellin Synthesis

- GA is a plant growth regulator
- It stimulates **cell division and cell elongation in stem**
 - Causes plant to grow tall
- Apply gibberellin to dwarf plants and they grow taller
 - **Dwarf plants** have inactive form of gibberellin
 - 2 forms: active and inactive



Role of Gibberellin in Stem Elongation

Control of Gibberellin Synthesis

1) Dominant allele (*Le*)

- Codes for **functional enzyme** needed in gibberellin synthesis pathway
- Enzyme converts inactive to **active** gibberellin
- Plants with at least one dominant allele grow to **normal height**

tall pea plant



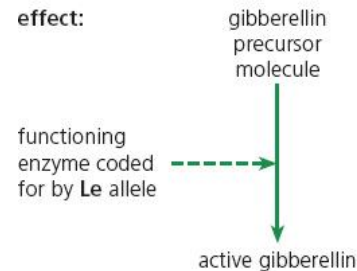
dwarf pea plant



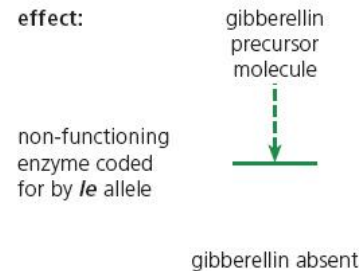
2) Recessive allele (*le*)

- Codes for **non-functional enzyme**
- Plants with 2 copies of the recessive allele cannot synthesise gibberellin
→ develop into dwarf varieties
- Dwarf plants have **inactive** form of gibberellin

alleles present: *Le Le* or *Le le*



alleles present: *le le*



Role of Gibberellin in Stem Elongation

How it works

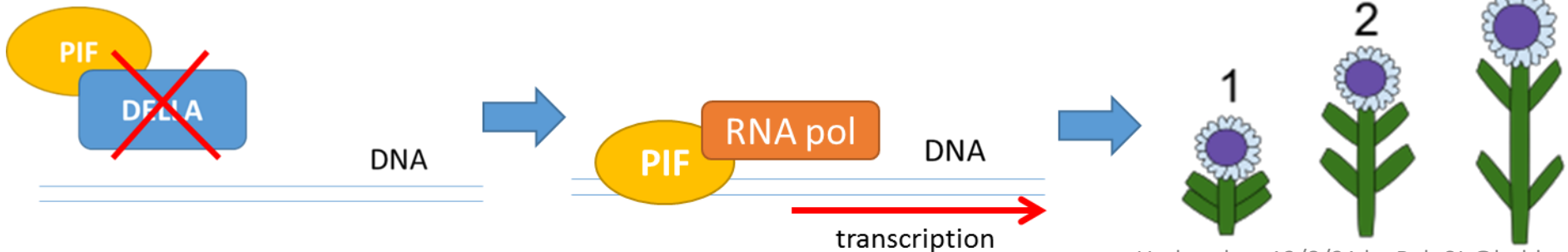
Without GA:

- **Transcription factor** (i.e. PIF) **attached to DELLA protein**
- PIF cannot bind to DNA



When GA binds to **receptor**:

- **causes DELLA protein destruction**
- inhibition of transcription removed
- PIF **binds to DNA**
- PIF recruits **RNA polymerase to bind to DNA**
- **Growth genes switched on**



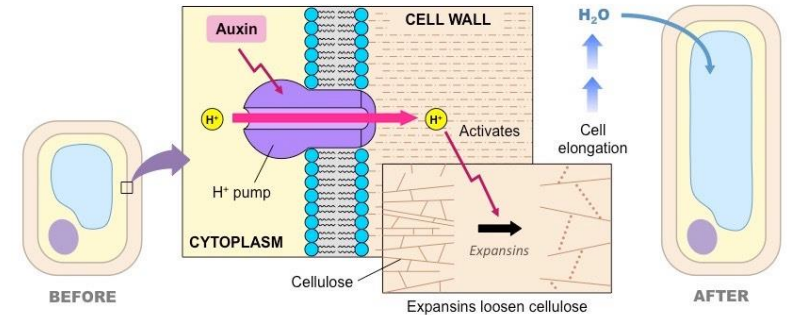
Role of Gibberellin in Stem Elongation

How it works

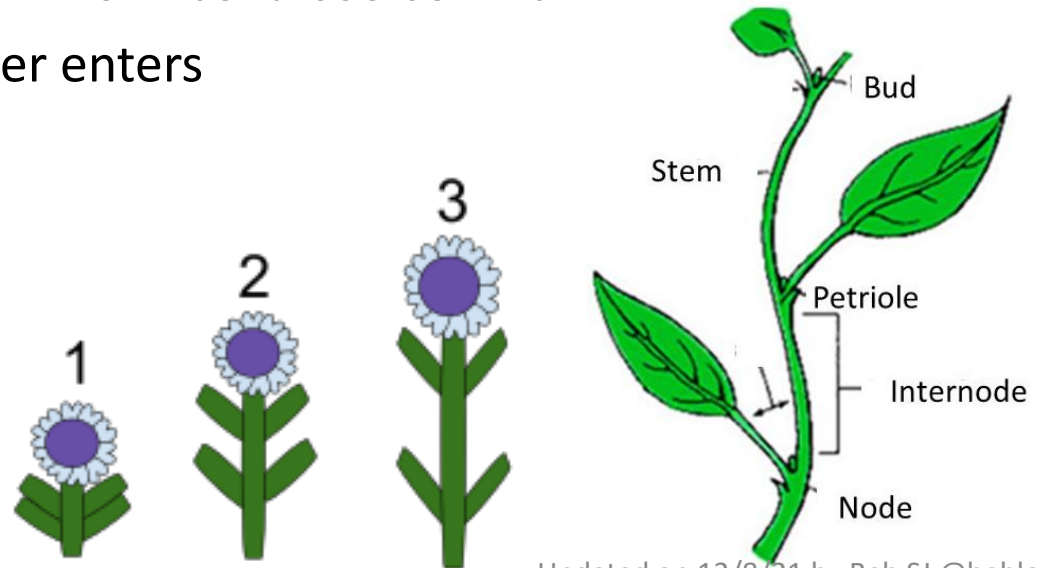
- Growth genes switched on
1. Causes **cell division** in stem

2. Causes **cell elongation** in stem

- **By interacting with auxin**
- Loosens cell walls by **acid growth hypothesis**
- Uses expansins to break cross-links in cellulose cell wall
- So cells can expand when water enters
- Changes plasticity of cell wall



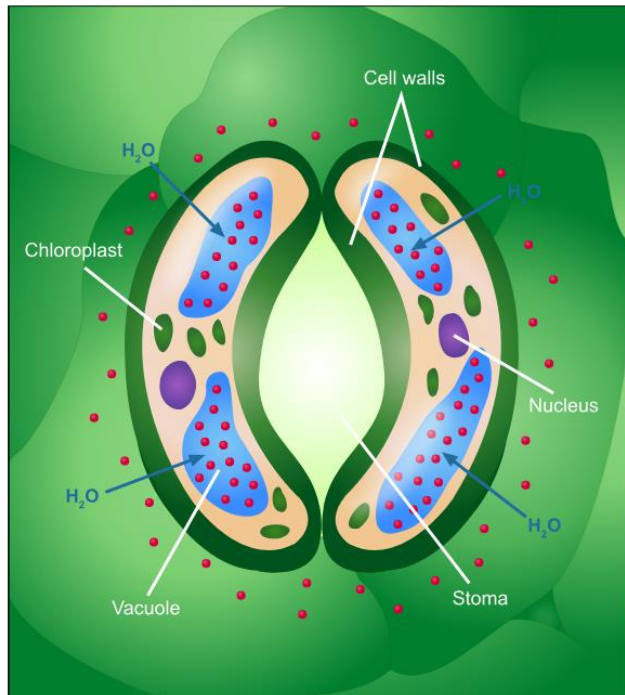
3. increases **internode length**



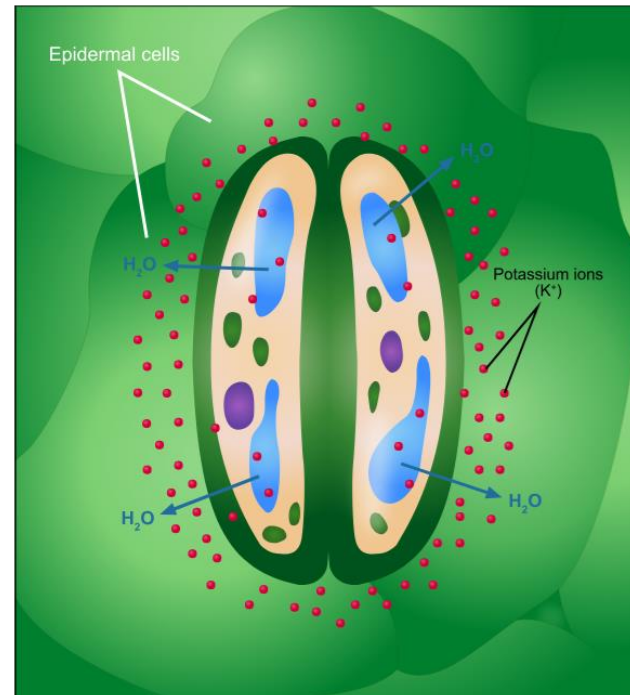
Guard Cells

- Each stomatal pore is surrounded by 2 guard cells
- Sausage-shaped cells with chloroplasts
- Highly specialized cells

Turgid – open



Flaccid – close

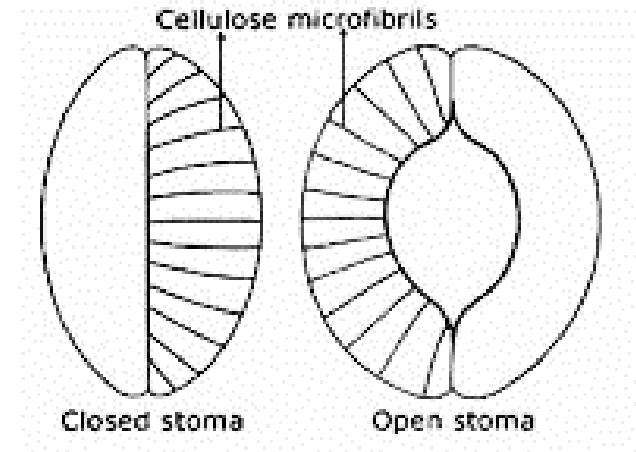
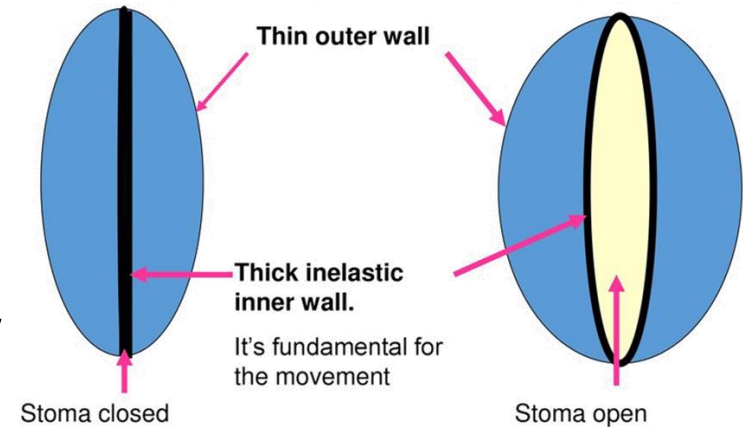


Guard Cells

Characteristics:

- a) **Unevenly thickened cell walls** with ends of cells joined
 - Wall adjacent to pore is very thick
 - Wall furthest from wall is thin
 - When turgid, thinner wall bends more readily than thicker walls
 - Opens pore

- b) Bundles of **cellulose microfibrils arranged as hoops** around the guard cells
 - When turgid, cell increase in length & not diameter
 - Cells will bend and curve when length increased



Stoma Opening Mechanism

1. **Proton pumps** in cell surface membrane of guard cells

- **Pumps H^+ ions out** of the guard cells
 - Low H^+ concentration in guard cells
 - Inside of cell more negative than outside
- Electrochemical gradient formed

2. This causes **K^+ channels open**

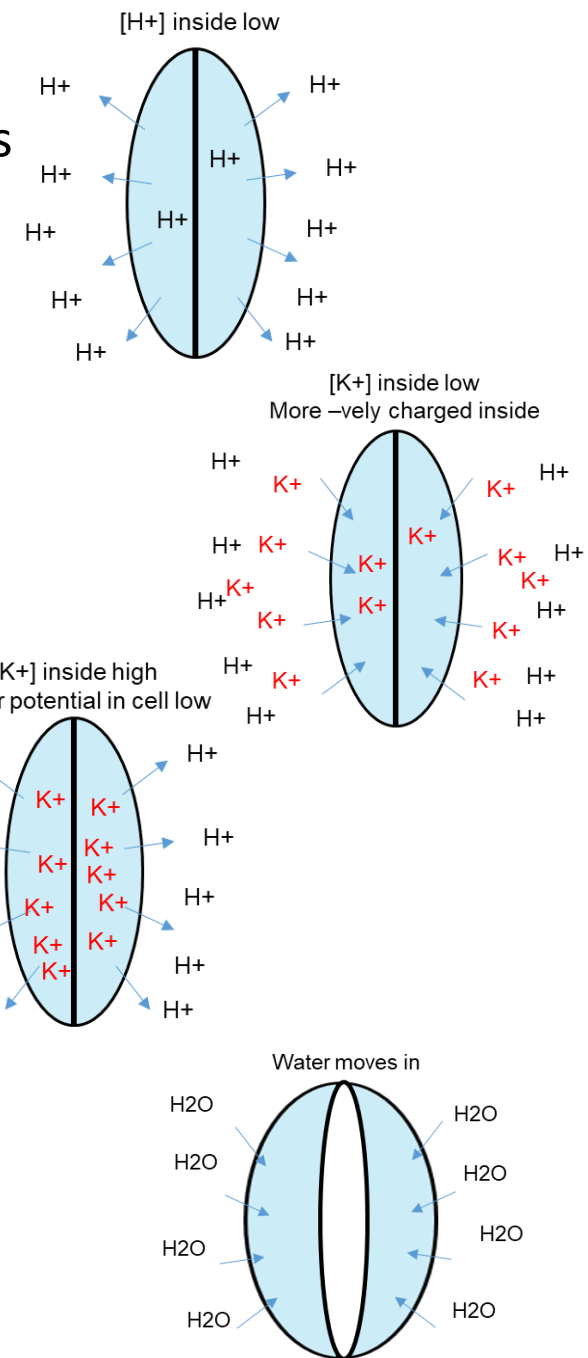
- **K^+ enters** via faci diff
 - **Cl^- diffuse in**
- Water potential of cell decreases

3. **Water moves in** by osmosis

- Via aquaporins

4. Volume of guard cells increase

- Become **turgid** and curve due to unequal thickness of cell wall → Pore opens



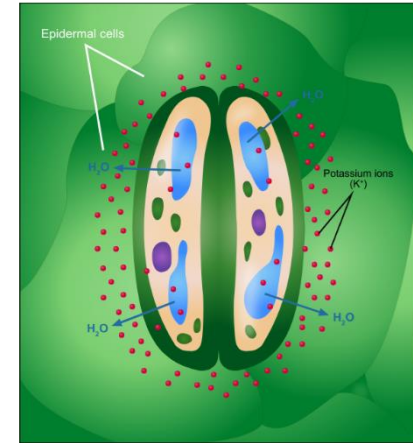
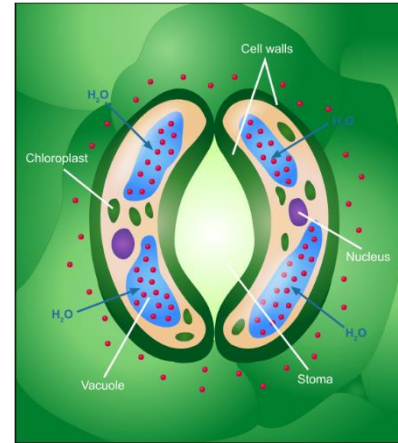
Stomatal Responses

Stomata opens in response to:

- Increase in **light** intensity
- Low CO_2 concentration in air spaces of leaf

→ Gain CO_2 for **photosynthesis**, allow O_2 out

→ Allow **transpiration** to occur → brings water and mineral ions in



Stomata closes in response to:

- Decrease in **light** intensity
- High CO_2 concentration in air spaces of leaf OR CO_2 not required bcs no photosynthesis
- Low humidity / high temperature / high wind speed / **water stress**

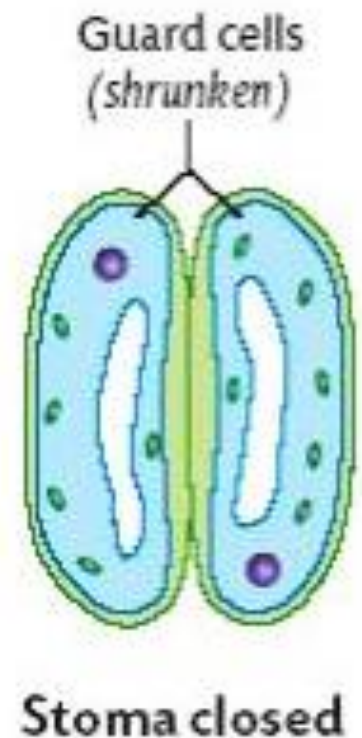
→ Maintain cell turgidity and **prevent water loss** by transpiration

3) Absciscic Acid (ABA)

- Stress hormone
- Produced during **water stress** (e.g. very high temp, reduced water supply)
- Synthesised in all cells with chloroplasts or amyloplasts (similar to chloroplasts but got large starch grains and no chlorophyll)

Role: **Stimulate stomata closure**

- Reduces water vapour loss from leaves (transpiration)
- Reduce rate of CO₂ uptake for photosynthesis
- Fast response
- Do not regulate expression of genes



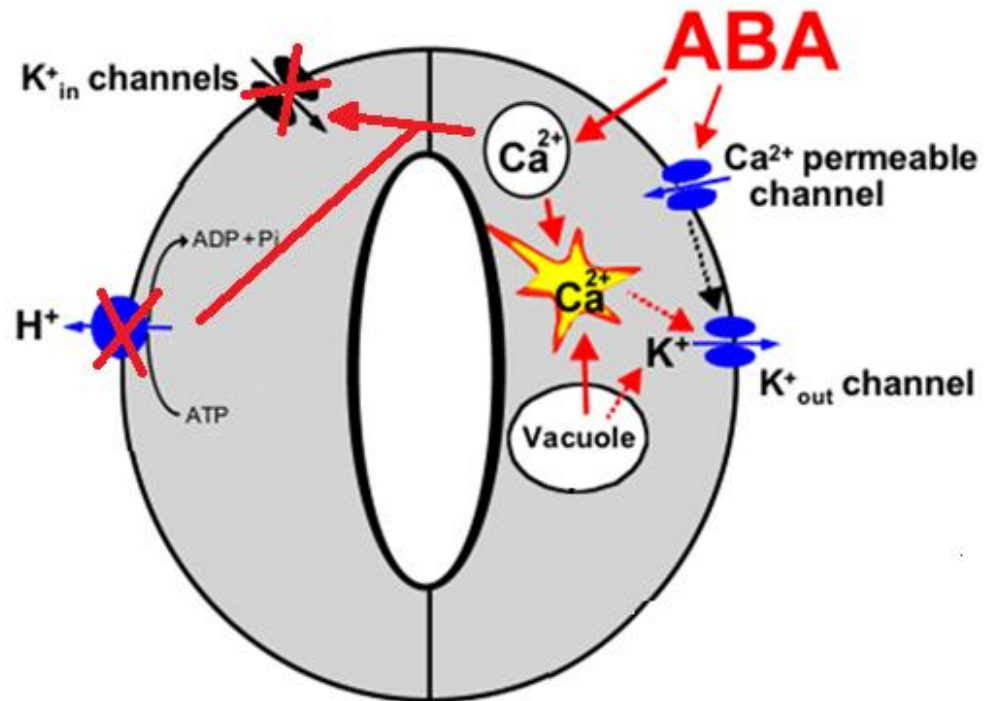
The Role of ABA during Water Stress

1. ABA is secreted and bind to **ABA receptors**

- On the cell membrane of guard cells

2. ABA stimulates **Ca²⁺ influx**

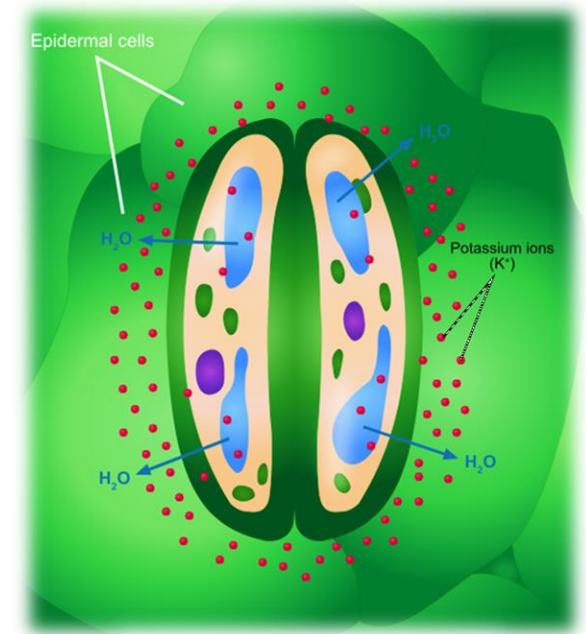
- From outside cell or inside vacuole into cytoplasm
- **Ca²⁺ acts as second messenger**
- Triggers a cascade of reactions



The Role of ABA during Water Stress

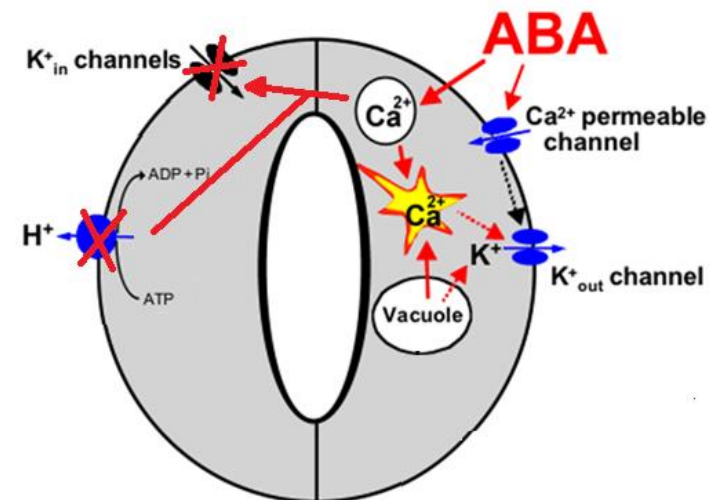
3. Calcium ions....

- **Inhibit proton pumps**
→ H^+ cannot move out
→ high H^+ conc inside cell
- **Inhibit K^+ influx**
- **Promote K^+ efflux**
- Activate channel proteins that allow -vely charged ions to leave the guard cells



4. Loss of ions **increases water potential** in guard cells

- **Water leaves by osmosis**
- Guard cells become **flaccid**
- **Stomata closes**
- Response is very **fast**



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 - calcium ions = second messenger